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Angora Rabbit Wool Production[1]

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IN THE United States garments made of Angora rabbit wool have been popular for many years, but only during the recent war years did domestic production expand to meet the demand of more than 120,000 pounds a year. Most of the publications on Angora rabbit wool are articles and booklets of breeders based on their personal experiences. A few experimental studies with Angora rabbits have been reported in Great Britain. In Germany, Angora rabbit wool has been examined for certain microscopic characteristics; also wool-production tests have been begun there. But on the whole the available information is meager. This valuable, soft, silky fiber has aroused much interest, and many questions bearing on its production and handling have been raised.

Some of the most common questions are the following: How often do Angora rabbits molt, and when; are there significant differences in individual yields; does season of birth have any effect on yield; what are the relative biological merits of shearing, clipping, and plucking; do retarded growth patches of wool on various parts of the body affect yield? To obtain information along these and related lines, the investigation reported in this circular was initiated in the Fish and Wildlife Service, United States Department of the Interior, in

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[1] This research was initiated in the Fish and Wildlife Service, U. S. Department of the Interior, July 1944. All activities pertaining to the production of fur animals in captivity (fur farming), including domestic rabbits, were transferred to the U. S. Department of Agriculture June 30, 1946, by act of Congress.

[2] We wish to acknowledge the substantial assistance given by Carl H. Holcomb and Robert M. Trimmer in caring for the animals, harvesting the wool, and making certain fiber measurements; the help given by Ralph G. Schott in the statistical analyses of the data; and the assistance given by Eunice P. Blair in keeping the records and in making some of the fiber measurements.

July 1944. All activities pertaining to the production of fur-bearing animals, including domestic rabbits, were transferred to the United States Department of Agriculture in 1946. The entire study was carried on at the Agricultural Research Center, Beltsville, Md.

Since the findings cover a wide field, the number of observations on any one phase is limited. The main contributions are the revelation of certain tendencies. The orientation so furnished should be followed up by more intensive studies along special lines.

DESCRIPTION OF ANGORA RABBIT WOOL

Angora rabbit wool is considered one of the textile specialty fibers, along with the wool from such other animals as alpaca, llama, vicuña, and cashmere goat. This wool is composed of two main types of fibers, the underfur and the guard hairs (fig. 1).

The underfur is soft, uniformly fine from tip to root, and crimped, or wavy. There are several kinds of guard hairs, but all are recognized by the enlarged tip, which makes these fibers coarse (*7*).[3] The guard hairs take the dye less readily than do the underfur fibers; hence Angora rabbit wool yarns often come in white or pastel shades. But with proper treatment, yarns of uniformly dyed dark colors can be produced. This situation, of course, enlarges the market for this product.

The tips of the guard hairs project from the yarn, giving it the characteristically fuzzy appearance. In outer garments this is desirable. On the other hand, for underwear, yarns with the fewest guard hairs are used for the softest texture. Thus it is understandable that there probably is no one "best" type of Angora rabbit wool; it depends upon the characteristics desired in the finished garment.

In actual practice the mills blend various proportions of different types of Angora rabbit wool, as has also always been customary in mills handling sheep wool. In fact, in order to manufacture articles having the desirable features of Angora rabbit wool but still within the reach of a substantial number of consumers, yarns are made with 50 percent, 40 percent, and sometimes even less Angora rabbit wool, the remainder usually being fine sheep wool, though other fibers such as rayon or silk are used at times.

ANIMALS USED IN STUDY

The white Angora rabbits used in this study were obtained as follows: Two unrelated does, bred to two different bucks, and an unrelated buck were purchased in July 1944. Each doe gave birth to a litter in July and November 1944 and in February and May 1945. Of the 53 young in the 8 litters, 44 lived to the end of the experiment and furnished complete information for analysis. Several animals of the last litters died as a result of a brief exposure to direct sunlight. None of the breeding animals were included in the study; furthermore none of the animals used in the test were bred.

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[3] Numbers in parentheses refer to Literature Cited, p. 21.

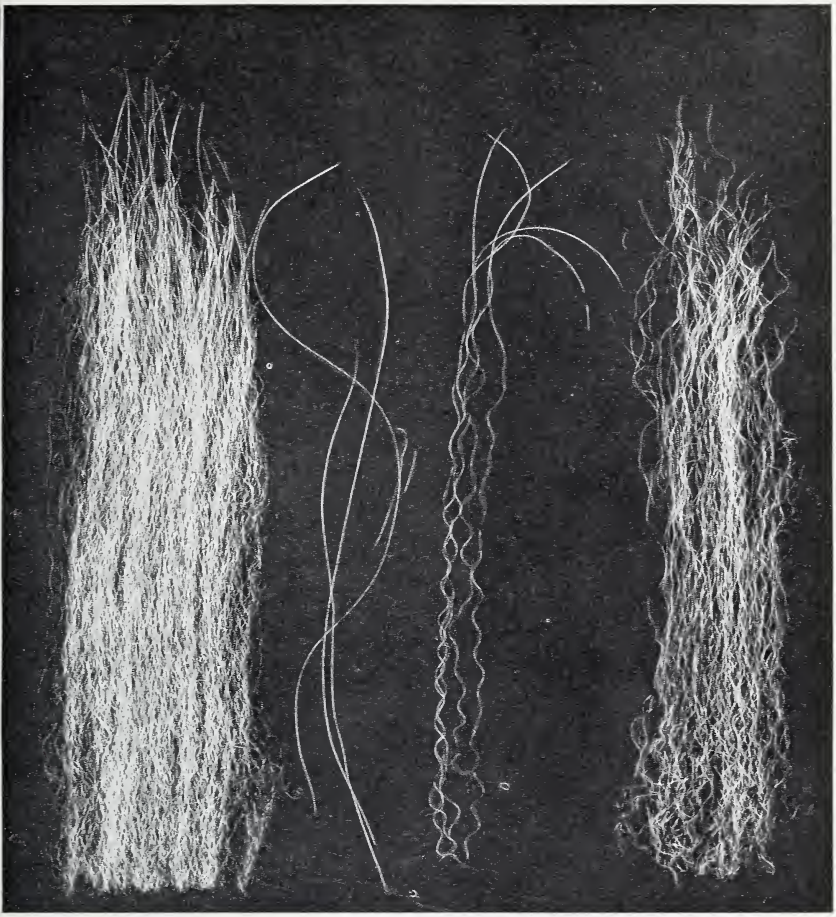

Figure 1.—The principal types of fibers in Angora rabbit wool. The coarser fibers with enlarged tips are guard hairs; the underfur is composed of the finer fibers.

EXPERIMENTAL METHODS

The rabbits were all housed in one large room of a brick animal building, which was heated during the cold season. The young were kept with the does until weaning time at 8 weeks. Thereafter each animal was kept in a separate metal "self-cleaning hutch."

Commercial so-called complete pellets were fed throughout. These pellets contained guaranteed 17- or 17.5-percent protein; sufficient soybean pellets were added to raise the protein to 20 percent. Alfalfa was available at all times, and fresh water was given daily. Greens gathered nearby were fed daily in the summer. When these were not available kale was fed three times a week. This is not a recommended

TABLE 1.—*Variations, among 44 Angora rabbits, in first year's mature-wool yield harvested during the molting periods and every 10 weeks by 3 different methods*

Molting periods			10-week periods			Designation of—	
Designation of rabbit	Sex	Wool yield (grams)	Designation of rabbit	Sex	Wool yield (grams)	Sire	Dam
			Shearing[1]				
B-2	Male	292				4A	328
B-6	do	288					
C-6	Female	209	C-7	Male	280	431	328
D-5	Male	241	D-7	do	247		
			E-1	do	268		
			C-5	Female	314		
			E-5	do	387		
B-12	Male	351				5A	400
B-14	Female	284					
C-17	Male	286	C-18	Female	281	431	400
			E-16	do	267		
			D-12	Male	282		
Total		1, 951			2, 326		
Average		279			291		
			Clipping[2]				
B-1	Male	181				4A	328
C-1	do	257	C-4	Male	215	431	328
D-2	do	236	D-1	do	258		
E-4	do	240	E-7	Female	304		
B-11	do	301				5A	400
C-14	do	249	C-16	Male	255	431	400
E-12	Female	255	D-14	do	305		
			E-15	do	266		
			C-15	Female	313		
Total		1, 719			1, 916		
Average		245			274		
			Plucking[3]				
B-3	Male	173				4A	328
B-5	Female	321					
D-4	do	124	C-3	Female	318	431	328
E-2	do	213	D-3	do	195		
E-3	do	163	E-6	do	200		
B-13	do	238				5A	400
B-15	do	249					
C-11	do	102	C-12	Female	327	431	400
C-13	do	341	D-15	do	269		
D-13	Male	222					
Total		2, 146			1, 309		
Average		215			262		
Grand total		5, 816			5, 551		
Grand average		242			278		

[1] Total average..285 grams.
[2] Total average..260 grams.
[3] Total average..230 grams.

general feeding schedule; it was devised to assure success of the experiment notwithstanding the fluctuations in quality of feeds imposed by wartime conditions.

The animals of the eight litters were distributed as evenly as possible with regard to season of birth, sex, and litter make-up into three major and six minor groups. Each of the three major groups was assigned to one of the methods of harvesting the wool, namely, shearing, clipping, and plucking. One-half of each major group was harvested at every molting period; the other half was harvested every 10 weeks as is prevalent in many commercial rabbitries (table 1).

When the rabbits were 8 weeks of age, the "baby wool" was removed, each animal being harvested by the method of the group to which it was assigned. The only exceptions were the first four animals assigned to the plucking group; these animals were inadvertently sheared. The data in this study include observations on the wool grown during the 12 months after the removal of the baby wool. In this report it is called the first year's mature wool growth or simply the mature wool.

Samples of wool taken from the loin region were measured by microscopic methods to discover what relations, if any, existed between characteristics of the fibers and certain features of the wool, such as matting.

OBSERVATIONS

MOLTS

Since the most valuable product of Angora rabbits is the wool, two important questions emerge at once in connection with the harvesting procedure: How often do Angoras molt, and when does molting occur? Mature short-haired wild rabbits are known to molt twice a year, in spring and fall (*18*).

On white Angora rabbits it is difficult to recognize the exact times of initiation and termination of molt. Nevertheless an animal can be identified, within a very few days, as being in full molt by the loose hairs clinging to the sides and top of the hutch, the loose hairs appearing when the coat of the animal is stroked with the hand, and the ease with which tufts of hairs can be plucked from the body. At this time the hair is approximately 3 to 3½ inches long. The Angora rabbits used in this study were in molt four times a year. These periods were pronounced, occurring in January, April, July, and October (fig. 2). These four molting periods are in agreement with the observations of many breeders. They differ, however, from the condition reported by Wucherer (*24*), and by Chambers (*5*), who stated that there is no definite period of molt in these animals.

Other queries along this line relate to the extent of the molt over the body of the animal and also to the sequence of shedding and priming over parts of the body (molting pattern). Reports in the literature disagree. Kidd (*8*) found on colored and white Angoras that "the moult proceeds over the chest, shoulders, low down sides, round the tail and rump, then follows the back, downwards on each side, till the last bit left is a narrow streak forming a complete circle round the rabbit." On the other hand McFarlane, Withers, and McCauley (*9*) note that the molt begins "between the back legs, working forward to under the chin, then shoulders and rump and along the sides." In the Beltsville herd, when an animal was recognized as being in molt, the long fibers appeared to be loose all over the body. It was not possible to observe consistently any sequence of shedding or priming on these white Angora rabbits; this point should be investigated further.

One also wonders whether the age of the animals affects their molting periods. In this experiment the litters were born in the four seasons, i. e. somewhat similar to the molt spacings; hence it would be necessary to have a herd with litters born every month of the year to clarify the picture. Furthermore, the animals should also be retained for a greater length of time than was possible in this instance.

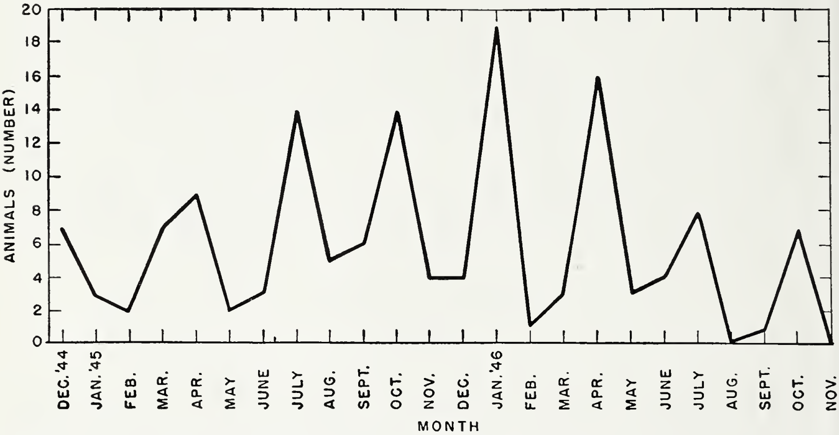

FIGURE 2.—Number of animals in molt by months (27 animals over a 2-year period).

VARIATIONS IN WOOL YIELD

The Angora rabbit's major returns are in the wool furnished; consequently the yield is of paramount importance. The matings of the rabbits used in this study were planned in such a manner that the offspring would exhibit as wide variations of characteristics as possible. That considerable differences in yield of wool were obtained is shown in table 1. The analysis of variance of total wool yield, according to the method of Snedecor (*17*), indicates that the differences in yield between the 44 individuals were significant (table 2).

The yields ranged from 102 to 351 grams per year, or from approximately 3.6 to 12.4 ounces per year (28.4 grams=1 ounce). The average for the herd was 258 grams (9.1 ounces). Pickard (*12, 14*) reported that there was great variation in the production of wool from different rabbits. The average yield calculated on the basis of 24 to 80 animals harvested at four periods of a year was 201.6 grams (7.1 ounces) (*12*). Wilson (*23*) reported an average annual yield of 196 grams (6.9 ounces) for 32 animals. Tegtmeyer (*20*) reported an average of 350 grams (12.3 ounces) but did not mention the number of animals observed.

The question naturally follows whether any great differences existed between the mature wool yield of the eight litters. Statistical analysis of the data by the same method as above, allowance being made for difference in size of litters, gave no indication of any significant differences between the litters in this respect. In other words, the individuals in different litters varied greatly among themselves in wool yield.

This information also sheds light upon another matter of interest. Since these litters were born during the four seasons of the year, the season of birth of the animals had no effect upon the annual yield of mature wool. Pickard (*11*) suggested that "April born youngsters" would produce the highest yield of wool during their first year of life. Pickard apparently included the baby wool, which was excluded in the present study. But of greater import in the two experiments is probably a difference in feeding. Whereas the animals at Beltsville were fed as uniformly as possible the year around, Pickard ascribes the observed increased wool yield of April-born rabbits to nutritional causes, implying that the feed was better during the first 6 months, i. e. until October.

TABLE 2.—*Yields between individual rabbits used in study*

Source of variance	Degrees of freedom	Sum of squares	Mean square	F value
Between individuals harvested at 10 weeks	19	7, 822	412	[1] 1. 65
Between individuals harvested in molt	23	22, 711	987	[2] 2. 07

[1] Statistically significant.
[2] Highly significant.

There are breeders who retain only does for wool, since they consider that bucks produce less wool. This view is held by Wilde (*21*), who reported that the annual wool production of females was 18 percent greater than that of males. However, neither Pickard (*13*) nor Wilson (*22*) found significant difference in the wool production of the two sexes. The findings in the present study agree with the latter two. The analysis of variance (*17*) demonstrated no significant difference in wool production between the sexes in the Beltsville herd.

In culling their animals some breeders stress body weight: They claim that it is more economical to keep the small animals. This idea is apparently based on the assumption that animals of different sizes yield approximately the same weight of wool. Smaller animals eat less than large animals; hence these breeders assume it would cost less to produce a given amount of wool from the small animals. On the other hand, other breeders have observed that some of their heaviest animals produced the greatest amount of wool in their herds, and they have naturally retained those animals. The data on the Beltsville herd, however, and the scatter diagram with regression lines fitted by the method of least squares (fig. 3) show a slight positive relation between increased body weight and increased yield of wool.

However, there is wide variation: There are very light-weight animals that produce much wool, also heavy animals that produce little wool. Consequently, the soundest procedure for selection would be to take both body weight and wool yield (*14*) into consideration. Wilde (*21*) suggested that the animals yielding the greatest weight of wool per kilogram of body weight were the most efficient producers. Thus the smallest animals are not automatically the most efficient. Indeed, he found that there were animals which, for a given percentage increase in body weight, produced a much higher percentage increase in wool yield than other animals; these would be the animals to keep.

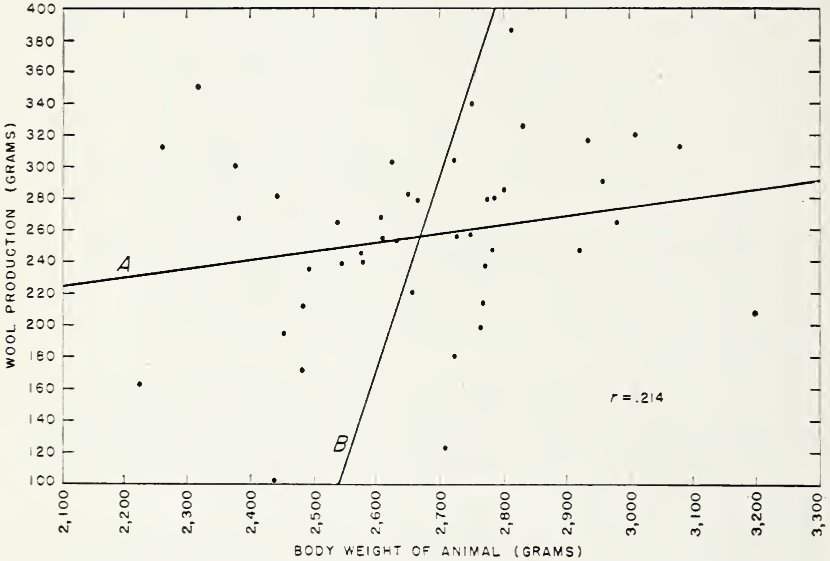

FIGURE 3.—Scatter diagram of the relationship of mature-wool production to body weight, showing the regression lines: *A*, Mature-wool production of animals of designated body weights; *B*, average body weights of animals having given levels of wool production.

In table 3 is shown the average yield per individual for each harvest, both for the group harvested in molt and for the group harvested every 10 weeks.

The table discloses that in each group there occurred one harvest in which the average yield per animal was extremely low: the fourth harvest of the first group (48.9 grams, or 1.7 ounces) and the fourth harvest of the second group (43.7 grams, or 1.5 ounces). Although these harvests do not coincide in the calendar year, both represent the growth of wool on the animals during midsummer. The analysis of variance for the wool yields (*17*), summarized in table 4, indicates that the differences between harvests were significant when the animals were harvested five times a year (at 10-week intervals), and highly significant when the harvests coincided with the natural shedding periods, four times a year.

TABLE 3.—*First year's mature-wool yield by periods, harvested at time of molt and every 10 weeks*

Period	Yield at time of molt (24 animals)			Period	Yield every 10 weeks (20 animals)		
	Mature wool yield	Average yield per animal	Deviation from year's average per animal per harvest [1]		Mature wool yield	Average yield per animal	Deviation from year's average per anima per harvest [2]
	Grams	*Grams*	*Grams*		*Grams*	*Grams*	*Grams*
Dec.–Feb.	1,689	70.4	+9.8	Jan. 1–Mar. 18.	1,180	59.0	+3.5
Mar.–May	1,559	65.0	+4.4	Mar. 19–May 22.	1,139	57.0	+1.5
June–Aug.	1,395	58.1	−2.5	May 23–July 27.	1,229	61.5	+6.0
Sept.–Nov.	1,173	48.9	−11.7	July 28–Oct. 14.	873	43.7	−11.8
				Oct. 15–Dec. 31.	1,130	56.5	+1.0

[1] Year's average per animal per harvest=60.6 grams.
[2] Year's average per animal per harvest=55.5 grams.

TABLE 4.—*Variance for wool yields by intervals of harvest*

Source of variance	Degrees of freedom	Sum of squares	Mean square	*F* value
Between 10-week harvests	4	3,824	956	[1] 3.56
Between molt harvests	3	6,196	2,065	[2] 2.74

[1] Statistically significant.
[2] Highly significant.

HARVESTING METHODS

Each of the three accepted methods of removing the wool from the animals has its advocates. It is not the purpose of this study to determine any "best" method. Under different conditions a breeder may prefer to clip or shear in the interest of saving time, or he may prefer to pluck to obtain the premium offered by the mills for plucked wool. The purpose of this phase of the study is to determine the biological effects of the various methods of harvesting the wool.

When the year's total wool production was considered, there was no significant difference (*17*) between the amounts obtained by plucking, clipping, or shearing. This is true both when the harvest occurred every 10 weeks and when it took place during the molt. However, in the production of No. 1 wool (table 5), the method and time of harvest did make a difference. When the harvest occurred every 10 weeks, only about 35 percent of the wool obtained by either clipping or shearing was No. 1 wool; whereas when the harvest occurred during the molt, about 55 percent of the wool was No. 1. When the wool was plucked, the percentage of No. 1 was considerably higher than when clipping or shearing was practiced, as might be expected.

TABLE 5.—*Effect of harvest interval and method of harvest on proportion of No. 1 wool*

Method of harvesting wool	Molting intervals			10-week intervals		
	Total mature wool	No. 1 wool		Total mature wool	No. 1 wool	
	Grams	*Grams*	*Percent*	*Grams*	*Grams*	*Percent*
Shearing	278. 71	155. 00	55. 61	290. 75	100. 86	34. 69
Clipping	245. 57	136. 14	55. 44	273. 71	91. 79	33. 54
Plucking	214. 60	143. 05	66. 66	261. 80	160. 40	61. 27
Average	242. 33	144. 52	59. 64	277. 55	112. 58	40. 56

Some of the yields of No. 1 wool obtained may seem low; however, this was neither a performance test nor an attempt to produce a high-yielding commercial herd. The experiment was planned to obtain answers to a number of questions, and some procedures in handling the animals were modified for this purpose. For example, sometimes No. 2 wool was harvested to keep to a schedule, when in actual practice a breeder would wait until there had been further growth before removing the wool.

Occasionally an animal was plucked to the "pink," i. e., practically all the wool was removed, leaving the skin exposed. The records of these animals showed that this condition usually occurred if (1) the previous harvest had been clipped, thereby removing any undergrowth present at that time; (2) No. 2 wool had been removed during the previous harvest; (3) the animal was on a 10-week harvest schedule; or (4) the animal had been ill. It is believed that if animals are plucked from the very first (i. e., beginning with the baby-wool harvest); are harvested only at the time of molt; and only No. 1 wool is plucked each time, they will normally be left after the harvest with a covering of undergrowth 3 to 6 centimeters long (1 inch=2.54 centimeters).

RATE OF WOOL GROWTH

How much does the wool grow every day? To answer this question, a small area on the loin of an animal was selected from which the wool was cut off close to the skin. The new tuft of wool that grew in was tied with dental floss as soon as it was long enough. The thought was to tie this tuft each week close to the skin, similar to the method used on sheep, and so be able to measure the weekly growth. But rabbits are different: they chewed off the thread, including their own wool tuft, down to the very skin.

Another method was to shear a small area on the animal close to the skin and paint it with a dye. Although a number of stains were used, only one was found which would serve. The following faded in a few days: Carbol fuchsin, eosin, gentian violet, gold chloride, indigo carmine, malachite green, methyl red, methylene blue, orange G, potassium permanganate, safranin, and thionin. Silver nitrate formed a dark deposit on the fibers but was irritating to the skin. A solution of picric acid in 95-percent alcohol was fair but in 50 percent was very good. The brilliant yellow color of the picric acid stain penetrated the fibers well, was fast, and apparently did not disturb the animals. Fairly good measurements were obtained of the undyed, or white, portion of the fibers which grew subsequent to the dyeing. But after a time the line of demarcation between the yellow and white portions becomes somewhat blurred, apparently the result of somewhat irregular rates of growth of the individual fibers.

The most satisfactory procedure was to cut the wool from an area approximately 6×3 centimeters (1 inch=2.54 centimeters) in size, and then to measure at 10-day intervals the total length of the fibers as they grew in this selected area. One set of observations is shown in figure 4. The most conspicuous feature is the irregularity in the growth rate. Six animals were included in this study; the results of the other five were similar to the ones shown in the figure. Further, the rate of growth of the longer hairs, usually guard hairs, closely parallels that of the underfur fibers, but is slightly greater than that

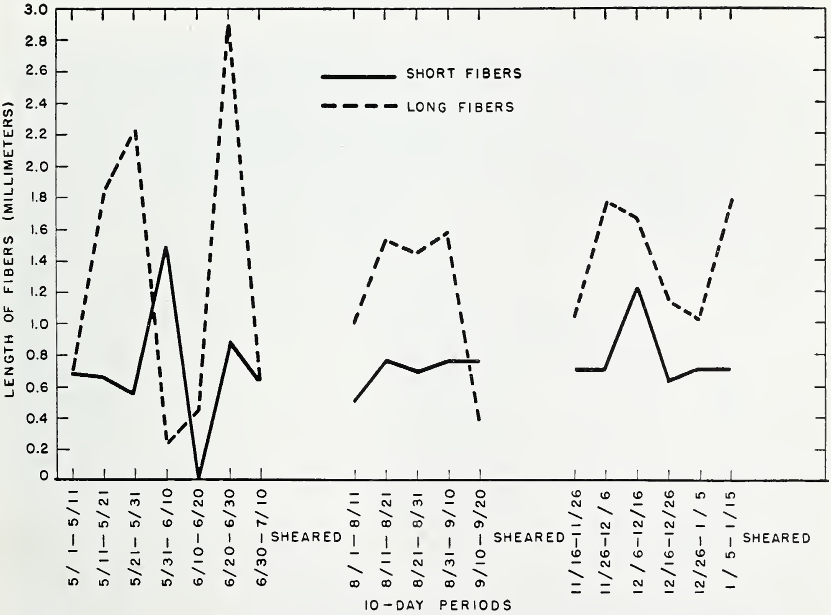

Figure 4.—Daily growth rate of the wool of Angora rabbit, D–5, calculated on the basis of total length of the fibers measured at 10-day intervals. The animal was sheared when in molt.

of the latter. This difference in growth rate of guard hairs and underfur was noticed by Chambers (*5*). He worked with "perhaps half a dozen animals" but gave no figures. Still another manifestation indicated in figure 4 is that the change in growth rate is suggestive of a normal curve, accelerating during a phase of new growth to a maximum and then decreasing sharply upon the approach of the shedding of the old fibers.

The average daily growth rate of wool on rabbit D–5 (shown in fig. 4) from May 1, 1945, to January 28, 1946, was 0.69 millimeter (1 inch = 25.4 millimeters). This measurement is similar to that obtained by others. Wucherer (*24*), apparently measuring only one animal over a 14-day period, recorded that the underfur grew 11 millimeters, the guard hair 16 millimeters, i. e., 0.79 and 1.14 millimeters per day respectively. Chambers (*5*), working with half a dozen animals over a period of about 100 days (no exact data given), gave the rate of growth as 1 millimeter per day as the average for the guard and the fine hairs combined. Burmeister (*4*), in a general report on performance tests in Demmin, Germany, mentions an average wool growth of 5 millimeters per week, i. e., 0.71 millimeter per day. No further details were given.

AREAS OF RETARDED GROWTH OF HAIR

As the new hair grows in after a harvest of wool, patches are sometimes observed for an indefinite period (fig. 5). These areas of retarded growth are of course most prominent if they are large and while the surrounding growth is still comparatively short.

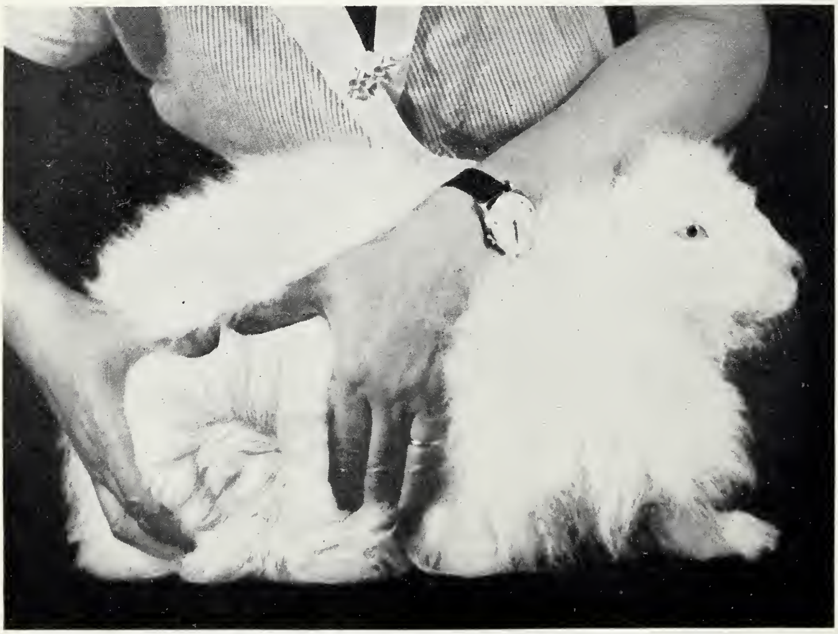

FIGURE 5.—A patch of retarded growth on the rump of an Angora rabbit.

In table 6, the 19 animals are listed on which patches of retarded growth of varying size were noted. On 43 percent of the herd some retarded growth was evident at one time or another; however, only in three cases, 7 percent of the herd, were the areas very large. The largest area, 15×10 centimeters, was found on B–14. New hair began to grow in around the edges of the patch after 70 days, but the area was not completely covered with growing hairs for 210 days. The largest areas on C–18 and C–6 were 10×6 centimeters, and did not disappear until 240 and 35 days respectively.

The data in this table also show that retarded growth occurs in animals whether they are clipped, sheared, or plucked. Tänzer (*19*) felt that the growth of hair was retarded when plucking was practiced. Pickard and Crew (*15*) encountered retarded growth in old rabbits. The truth seems to be that the cause of this localized retardation of fiber growth is not yet known. In the studies reported in this circular the patches of retarded growth occurred most frequently on the back and the rump, but also to some extent on the loin, sides, and belly. Retarded growth was observed in every month of the year; however, it was most frequently observed from June through September.

Retarded growth did not markedly influence the year's yield of either No. 1 wool nor total yield of wool in the Beltsville herd. Actually there was a slightly greater, though not significantly greater, yield than in animals with no retarded patches. The total yield of No. 1 wool and mature wool was 134 and 262 grams, respectively, for the 19 animals with retarded growth patches; 128 and 255 grams, respectively, for the 25 remaining experimental animals; and 130 and 258 grams, respectively, for the entire herd.

Matted Wool

One of the banes of a rabbitry is matted wool (fig. 6). Compared with No. 1 wool, matted wool, which rates as No. 4, is practically worthless. In order to obtain a better understanding of the relation of matting to other conditions, the observations on animals that produced 10 percent or more of the mature wool yield in mats were collected as shown in table 7. The most striking feature is that all animals producing mats in such quantity were males. Furthermore, 92 percent of the animals that produced mats were harvested when in molt, whereas only 8 percent (one animal) was in the group whose wool was harvested every 10 weeks. Hence it is to be expected that in animals which have a tendency to produce mats, the amount of free wool could be increased by harvesting at shorter intervals.

Mats were found to develop on every part of the animal. Also they were observed during every month of the year. Matting was most pronounced during hot weather and least during cold weather. The causes of matting of wool on some animals and not on others have not yet been determined. Microscopic analyses of the fibers showed certain trends, such as slightly finer fibers, fewer guard hairs, and wider crimp in wool that tends to mat. This point is discussed in detail under "Microscopic Analyses of Fibers." Nevertheless, further investigation is necessary to obtain a clear-cut solution.

During the winter of 1945, because of wartime conditions, it was impossible to obtain alfalfa of a quality that the animals would eat.

Table 6.—*Retarded growth patches on animals of experimental herd*

Method of harvesting	Designation of animal	Sex	Number of times retarded growth patches were seen on—					Month	Size of largest areas affected	Duration	Total wool yield	
			Rump	Back	Loin	Sides	Belly				No. 1	Mature
										Days	*Grams*	*Grams*
Sheared	C-7	Male	1					July			51	280
	B-12	do		2	2			Aug., Sept	One-quarter of back	20	163	351
	C-5	Female	2	1				June, Sept	Rump: from hip to hock.	21	119	314
	C-18	do	1	3	1			June, Sept., Dec	Back: 7 x 2 cm Back: 10 x 6 cm Rump	105-180 150-240 48	43	281
	E-16	do	2					May, June			127	267
	B-14	do	2	3	2	1		June, Aug., Oct	Back: 15 x 10 cm	70-210	168	284
	C-6	do	1	3		1	1	June, Aug., Sept., Dec.	Middle of back: 10 x 6 cm. Entire back	35 26	131	209
Clipped	C-1	Male					1	July	One-half of belly	30	128	257
	C-15	Female		2	1			Sept., Mar., Apr	Back: 8 x 6 cm	47	117	313
	E-12	do	2	1				Mar., June, July		28	255	255
Plucked	B-3	Male	1					Feb			82	173
	D-13	do				1		Aug			131	222
	C-3	Female	1					Nov			157	318
	C-12	do	2	1				Mar., Aug., Oct			179	327
	D-3	do					1	July			115	195
	D-15	do					1	July			197	269
	E-6	do	1					June			174	200
	C-13	do	1					Aug			132	341
	D-4	do	1	1	1	1	1	Jan			106	124

TABLE 7.—*Production data of Angora rabbits producing 10 percent or more of their mature-wool yield in mats*

Designation of animal	Sex	Wool harvested during molt								
		Percentage of No. 4 wool produced in—				Total No. 1 wool		Total No. 4 wool		Total mature wool
		Dec.–Feb.	Mar.–May	June–Aug.	Sept.–Nov.					
		Percent	*Percent*	*Percent*	*Percent*	*Grams*	*Percent*	*Grams*	*Percent*	*Grams*
B-2	Male	7. 9	29. 6	11. 8	15. 3	144	49. 32	49. 0	16. 78	292
B-3	do	9. 3	8. 5	15. 7	56. 3	82	47. 39	25. 5	14. 74	173
B-6	do	17. 1	33. 1	16. 4	5. 1	103	35. 76	52. 5	18. 23	288
B-11	do	6. 8	0	23. 9	31. 0	129	42. 85	44. 0	14. 61	301
B-12	do	4. 8	5. 9	40. 2	18. 8	163	46. 44	67. 0	19. 09	351
C-1	do	25. 0	5. 4	83. 6	0	128	49. 80	79. 0	30. 74	257
C-14	do	0	16. 9	5. 7	26. 0	125	50. 20	32. 0	12. 89	249
C-17	do	12. 8	1. 0	6. 1	22. 4	179	62. 59	28. 5	9. 96	286
D-2	do	12. 1	0	18. 6	14. 5	146	61. 86	30. 0	12. 71	236
D-13	do	21. 7	11. 5	56. 9	30. 6	131	59. 00	64. 0	28. 82	222
E-4	do	17. 6	10. 7	44. 2	23. 9	122	50. 83	54. 0	22. 50	240
Average [1]	do	13. 7	14. 4	29. 6	21. 1					

Designation of animal	Wool harvested every 10 weeks										
	Sex	Jan. 1–Mar. 18	Mar. 19–May 22	May 23–July 27	July 28–Oct. 14	Oct. 15–Dec. 31					
C-4	Male	0	5. 0	0	55. 5	0	40	18. 60	27. 0	12. 56	215

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[1] Weighted average.

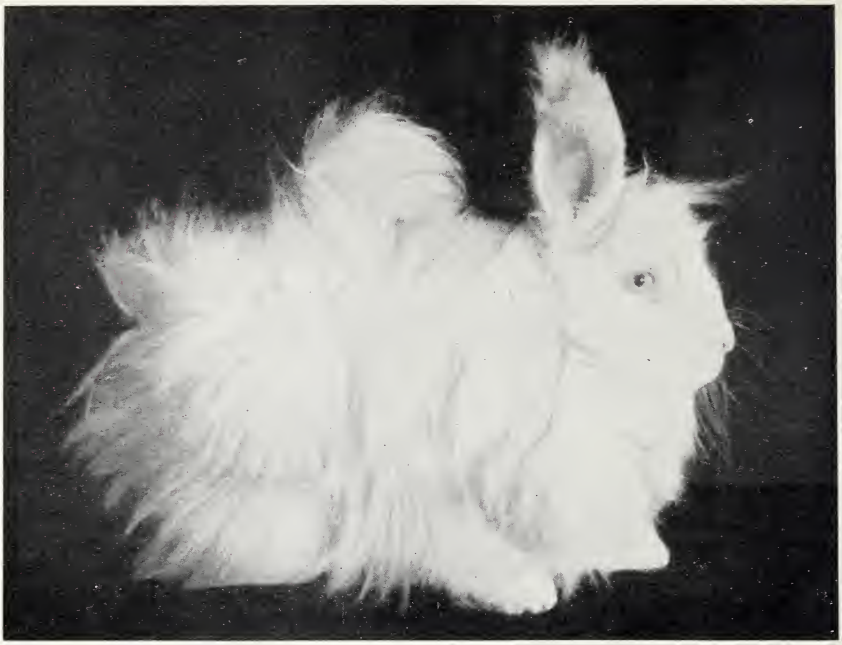

FIGURE 6.—Matted wool on Angora rabbit D–14; 28.8 percent of the mature-wool yield graded No. 4.

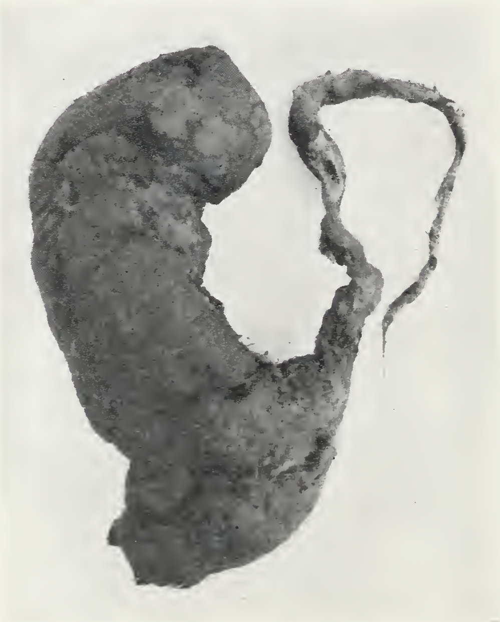

FIGURE. 7.—A large wool ball, taken from the stomach of an Angora rabbit, measuring 11×5.5×4 centimeters and having an appendix 17 centimeters long. (Photographed by E. R. Quortrup.).

About that time a considerable number of animals developed wool balls some so large as to cause death. The medium- and large-sized wool balls (fig. 7) occurred more frequently in the animals whose wool showed a tendency to mat, i. e. 75 percent of such balls occurred in this group whereas 25 percent developed in animals whose wool did not mat. In this connection, there was a tendency for animals that produced mats to chew their fur down to the skin. This chewing is no doubt associated with itching. It is well known that if, for some reason fibers shed or break on any wool-bearing animal, such as sheep, the broken fibers travel toward the skin. As the animal moves these free fibers move, are entangled with attached fibers, become webbed, and finally form felts or mats. These considerations point the way for further research on fiber characteristics in relation to the problem of matting.

Microscopic Analyses of Fibers

At the time of the last wool harvest from each animal in this experiment, a tuft of wool taken from the loin region was set aside for detailed examination. Since the abundance of guard hairs in Angora rabbit wool is a matter of general interest, counts were made on 500 fibers from the sample. This was done by making a cross section of the fibers, 1 centimeter above the root end, by means of the Hardy cross sectioning device (*6*). The cross sections were then projected at 500 diameters to facilitate counting. The wool from the 44 animals included from 0.4 to 8.6 percent of guard hairs and averaged 3.4 percent. Papsdorf (10) found 8 to 15 percent of guard hairs in Angora rabbit wool. Burmeister (*4*), who pointed out that the presence of guard hairs makes the wool hard and makes it feel sandy, said that there were about 95 percent of underfur fibers in the wool of first-class animals.

It is generally understood that in Germany Angora rabbit wool is used largely for underwear; consequently, Burmeister could be expected to look upon guard hairs as undesirable. Likewise, Burkhardt (*3*) recommended breeding practices that would tend to eliminate guard hairs. Tänzer (*19*) remarked that on the whole males tended to have a higher proportion of guard hairs than females. However, in the Beltsville herd this was not borne out; the males averaged 3.3 percent of guard hairs in the wool, the females, 3.6 percent.

In this country French wool, which is considered to be very good because it is said to contain much guard hair, is desirable for making outer garments. However, the microscopic analysis of four samples available, reputed to be of French origin, did not confirm this. In these samples from 1.8 to 3.4 percent of guard hairs were present, the average being 2.4 percent.

The fineness of Angora rabbit wool is one of the main features that contributes to the desirable texture of the articles made of it. Cross sections (*6*) made approximately 1 centimeter above the root ends of the fibers showed that the underfur was, on the average, 14 microns in diameter (1 micron=0.001 centimeter=0.000039 inch). These fibers were remarkably uniform, the range being from 10 to 18 microns. According to von Bergen and Krauss (*1*) and von Bergen and Mauersberger (*2*), vicuña averages 13 to 14 microns, ranging from 6 to 25 microns; cashmere averages 19 to 20 microns; camel hair averages about 18 microns, ranging from 9 to 40 microns; alpaca, 27 microns; fine sheep's wool, 10 to 20 microns; medium sheep's wool, 20 to 30 microns. Wucherer (*24*) and Plail (*16*) found the average of Angora rabbit underfur to be 12 microns; Papsdorf (*10*) found it to be 14 microns.

General references to the fineness or coarseness of various types of Angora rabbit wool may include not only the proportion of guard hairs present, but also the diameters of the guard hairs as well as of the underfur fibers. To find out whether a relationship existed between the fineness of the underfur fibers and the major diameter (i. e. at the thickest portion) of the guard hairs, these values obtained in the microscopic analyses were plotted on a scatter diagram (fig. 8). That there is a slight positive relationship between these two characteristics was confirmed by statistical analysis (*17*).

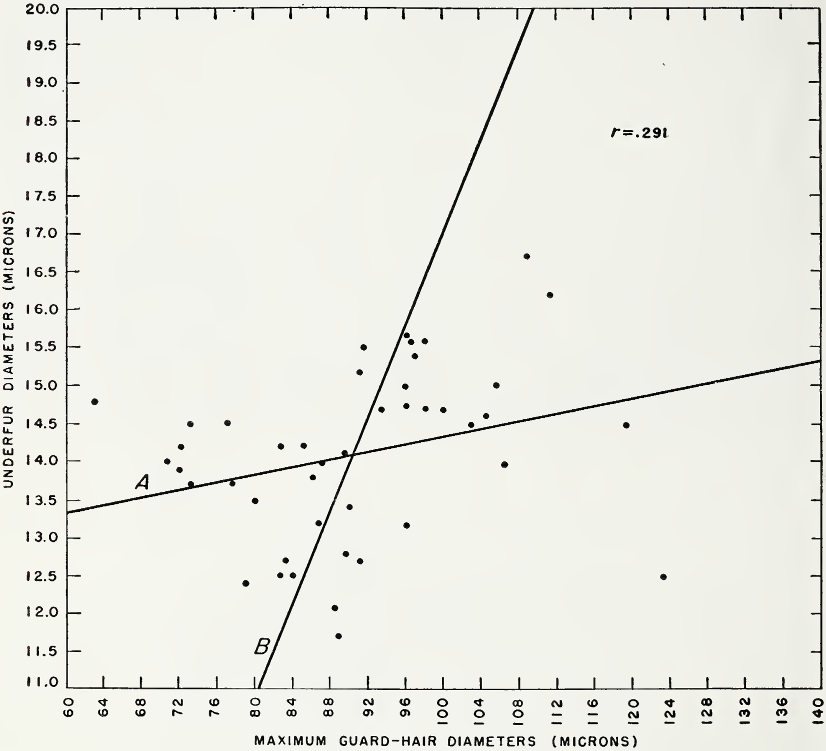

FIGURE 8.—Scatter diagram of the relationship of underfur fineness to maximum guard-hair diameter, showing the regression lines: *A*, Diameter of underfur in animals having designated maximum guard-hair diameters; *B*, maximum diameter of guard hairs in animals with indicated underfur diameters.

There are those who think that the fineness of the fibers might be affected by the method of harvesting the wool. For this reason the wool from the sheared, clipped, and plucked animals was analyzed for diameter of the underfur, diameter of the thickest portion of the guard hair, percentage of guard hair, and size of crimp. However, the values obtained were all similar.

In seeking for an explanation for the matting of the wool of some animals and not of others, it was found that neither the fineness of the underfur nor the fineness of the guard hair (maximum diameter) alone indicated whether an animal was prone to matting or not. However, when the data were arranged as shown in figure 9, it was evident that the animals with wool mats are more apt to be animals with the finer fibers than those with the coarser fibers. This finding corroborates those of Pickard and Crew (*15*).

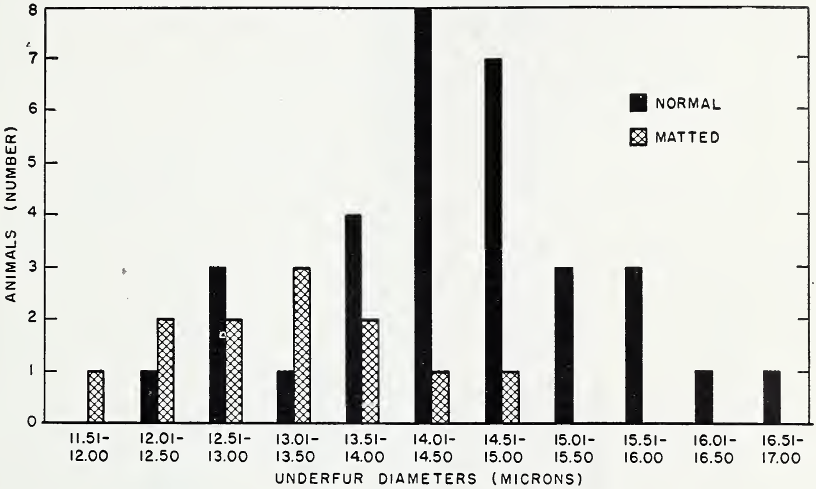

Figure 9.—Distribution, according to fineness of underfur, of animals with normal wool and animals with wool prone to mat.

Burmeister (*4*) felt that the presence of some guard hairs was desirable since they gave the necessary support to the underfur fibers and thereby decreased the danger of felting. However, data in the present study show no relationship between the ratio of guard hair and underfur and the tendency of wool to mat.

In the Beltsville herd, however, a relationship was found between length of crimp and tendency of wool to mat (fig. 10). In the rabbit, crimp is two-dimensional, i. e., when the fiber drops on the table it falls flat on one side, as pointed out by Wucherer (*24*). Fibers for the crimp measurements were mounted on plastic sheets. Cellulose acetate film, cut to a size of 3¼ inches by 4 inches, will hold approximately 50 Angora rabbit fibers. To anchor the fibers in place for accurate measurement, tributyl phosphate is spread evenly on the film with a camel hair brush. The underfur fibers to be measured are picked up with straight, blunt-edged forceps and arranged in a row on the moistened cellulose acetate film with the aid of a fine brush or dissecting needle. When the fibers are in place, the film is dried at 85° C. for not more than 30 minutes. A longer heating time will produce a loosening of the fibers from the mount.

At the end of this time the temperature is reduced to a little above room temperature (about 30° C.) until the fibers are dry, perhaps another 30 minutes. Overnight drying at the lower temperature is even better. If the film shows a tendency to curl up, weights are placed on the corners to keep it flat. When the fibers are ready for measurement, the film is placed between lantern slides and projected at a magnification of 10 ×. The length of the crimp is obtained by measuring from the crest of the crimp or wave nearest the tip to the crest of the crimp nearest the root end; this figure is then divided by the total number of crimps in the fiber.

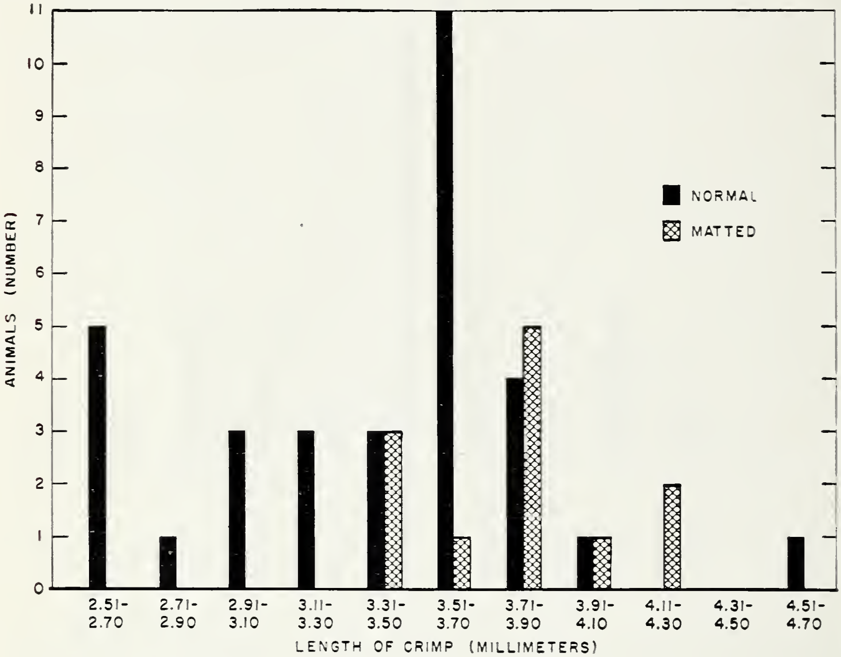

FIGURE 10.—Distribution, according to length of crimp, of animals with normal wool and animals with wool prone to mat.

The same method may be used to mount guard hairs to measure the maximum diameter (through the thickest portion) of these fibers. To make sure the measurements are taken at the thickest portion of the guard hair, it is necessary to move the slide back and forth until the desired position is reached on the screen. If only an approximation is needed, results can be obtained somewhat more rapidly with the use of a photographic enlarger at a magnification of about 12.5 ×.

SUMMARY

The factors affecting Angora rabbit wool production were surveyed by experimentation with 44 animals for a 12-month period after the removal of the "baby wool" at 8 weeks. The rabbits were kept in individual hutches in a brick building at Beltsville, Md., fed uniformly throughout the year, and were not bred.

These Angora rabbits were in molt four times a year, the peak months being January, April, July, and October.

There was a significant difference in yield between the individual animals, but no significant difference between the litters.

A slight positive correlation was found between increased body weight and increased yield of wool.

The growth of wool during midsummer was lower than at other times of the year.

There was no significant difference between the total amounts of wool obtained during the 12-month period whether it was plucked, clipped, or sheared and whether it was harvested every 10 weeks or at the time of molt. But a greater proportion of the yield was No. 1 wool if the harvest occurred at the time of molting than at every 10 weeks, whether by plucking, clipping, or shearing. The largest percentage of No. 1 wool was obtained by plucking at the time of molt.

The season of birth of the animals had no effect on the total first year's mature wool growth. Furthermore, there was no significant difference in wool production between the sexes.

The rate at which the wool grew was irregular but, on the average, amounted to about 0.7 millimeter per day.

Retarded growth of wool, i. e., patches of skin on which the wool failed to grow for some time, occurred in clipped, sheared, and plucked animals, particularly on the back and rump, and was not related to sex. These patches occurred most frequently during the summer. Their presence did not appear to influence markedly the year's yield of No. 1 nor total yield of wool.

Mats occurred repeatedly on some animals, not on others. They were observed throughout the year but were most prevalent during hot weather. Mats materially reduced the yield of desirable wool. Only males exhibited mats amounting to 10 percent or more of the total yield. The mats were more prominent on animals harvested at the time of molt than on animals harvested every 10 weeks.

Microscopic analyses of the fibers showed that (*1*) the percentage of guard hair in wool from males and from females was similar; (*2*) mats were more apt to form on animals having fine underfur fibers than on animals having coarser underfur fibers; (*3*) there was no relationship between the percentage of guard hairs in the wool and its tendency to mat; (*4*) wool with the longer crimp was more apt to mat than wool with the shorter crimp; (*5*) method of harvest had no effect on fineness of the wool; and (*6*) there was a relationship between the maximum diameter of the guard hairs and the fineness of the underfur.

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